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BT Response to the Ofcom consultation on:

”Higher power limits for licence exempt devices”

(Issued by Ofcom on 12 July 2006)

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EXECUTIVE SUMMARY

1. BT welcomes this Ofcom consultation on higher power limits for licence exempt devices and the opportunity to express our views on this issue. Wi-Fi technology is of major importance to both our domestic and business customers. BT operates an extensive network of public Wi-Fi hot-spots in the UK and we are a major supplier of Wi-Fi based broadband products and new / future Wi-Fi based services such as BT Fusion. Ofcom’s proposals are therefore of significant importance to BT and we believe that we are uniquely positioned to respond objectively to the issues raised.

2. After detailed technical analysis BT is of the opinion that Ofcom should permit a modest general increase in power levels for new 2.4GHz Wi-Fi devices to, at most, 500 mW e.i.r.p. This higher power should only be available to Wi-Fi devices which support full interoperability with 802.11 b and g devices (this includes normal operation of 802.11n devices). We do recognise that the case for increasing 2.4GHz Wi-Fi power limits is finely balanced since, although increased power can potentially improve Wi-Fi coverage, it can also lead to interference or reduced capacity between systems. BT notes that the newer Wi-Fi standards based on "MIMO" (multiple input multiple output) technology are already improving customers' experience of performance and coverage of Wi-Fi networks even without any increase in the present power levels. Nevertheless, we have concluded that a small general increase in power would be beneficial in terms of improving coverage in circumstances such as larger houses, certain offices etc. Available maximum power in common Wi-Fi devices and battery life considerations would limit the practical realisation of the benefits and the higher allowed power would not be used in all cases.

3. BT is concerned that Ofcom is only able to look at higher power in a small part of the 2.4GHz Wi-Fi band as this raises concerns about congestion if devices become concentrated in only part of the band. To realize the benefits to consumers the small increase in Wi-Fi power levels suggested above would need to be available across the whole band. We therefore urge Ofcom to negotiate further with MOD to explore the possibility of addressing the whole band.

4. BT would be very concerned if there is any intention to consider allowing higher powers for Video senders and other types of devices in the 2.4 GHz band. These devices operate in the 2.4GHz band but, unlike Wi-Fi, do not share spectrum in a "polite" manner since they cannot detect the presence of other wireless devices operating in the same location. Allowing such devices to increase their power would create serious additional interference problems which would disrupt Wi-Fi uses.

5. BT does not support the Ofcom proposal to allow 10W transmitter power in the 2.4GHz band. Increased power levels above the modest general increase for Wi-Fi that BT proposes (at most 500mW eirp) should not be allowed. We believe that introducing high power levels in the rural areas (specific geographic restrictions)

will be impossible to police and there is a serious risk of interference to Wi-Fi systems. The economic analysis of the benefits of rural fixed wireless access that under pins Ofcom's technical proposals is questioned by BT. We have reservations over several of the key assumptions made by Ofcom’s consultants and consequently have concerns about the accuracy of the conclusions on economic benefits.

6. BT supports the proposed increase in 5.8 GHz e.i.r.p. limits from 2W to 4W. We very much welcome Ofcom's proposal as this will improve the coverage and performance of broadband wireless access networks deployed in this frequency range. BT had requested Ofcom to make this change to the regulations and has been fully involved in the international technical studies that demonstrated that sharing with satellite systems is feasible in this band at this increased power level. We urge Ofcom to implement this change at the very earliest opportunity. BT also agrees that the register of 5.8 GHz assignments should be open.

7. We would be willing to meet with Ofcom to discuss any of the points raised in our response to this consultation document in more detail should Ofcom require.

BT response to the Ofcom consultation on:

"Higher power limits for licence exempt devices"

1. INTRODUCTION

BT welcomes this Ofcom consultation on higher power limits for licence exempt devices and the opportunity to express our views on this issue.

BT operates an extensive network of public Wi-Fi hot-spots in the UK, providing access to about 8000 hotspots (and rapidly increasing) and enabling access for our customers to about 30,000 hotspots worldwide. We are a major supplier of Wi-Fi based broadband products and new/future Wi-Fi based services such as BT Fusion. Ofcom's proposals are therefore of significant importance to BT and we believe that as a result of this operational experience and taking into account our research capability in this area and our participation in international standards development we are uniquely positioned to respond objectively to the issues raised.

The UK has in the past shown welcome leadership in opening up the 2.4GHz and 5GHz bands in 2002 for public mobile services using Wi-Fi technology ahead of the rest of Europe, which has subsequently followed. Ofcom is continuing this trend with the current consultation activity and we would encourage Ofcom to downstream any changes that may be decided into the European arena via bodies such as CEPT, ETSI and the EC.

In section 2 and Annex 3 we provide comments on the Scientific Generics techno-economic study that we understand forms a basis for the proposals that Ofcom had made. In Sections 3 and 4 we comment on the issues relating to the 2.4 GHz and 5 GHz bands respectively that we believe to be important and relevant to the subject of the consultation document. In Annex 1 we provide answers to the specific questions that Ofcom has posed, with cross-referencing back to the main text were necessary.

2. GENERAL COMMENTS

2.1 Scope

BT has assumed that the scope of the consultation document is wide ranging and potentially covers all licence-exempt uses of the 2.4 GHz and 5 GHz bands. The text of the document is not precise on this point but we believe that the issue of general Wi-Fi power limits and other devices such as video senders are in scope. We note also that the title of the document refers to licence-exempt devices but that licensed use of the 5.8 GHz band is also addressed in the document. We assume that Ofcom does not intend to make the 5.8 GHz band licence-exempt in the foreseeable future, but if this is not the case it would be helpful for this to be clarified.

2.2 The Scientific Generics Study

BT has reviewed the Scientific Generics study and in particular has looked closely at the calculations that came to the conclusion that a net consumer surplus of £443m would result from allowing 10W e.i.r.p. for 2.4GHz wireless access systems in rural areas. We have significant concerns with some of the key assumptions used in the study and we believe that the net benefits are considerably over-stated.

In terms of the costs of interference from high power systems we are concerned as to whether the costs to residential as well as business users should be considered. Apart from the impact of interference in terms of business and consumer confidence in Wi-Fi, we would note that the cost of £100/user may not reflect the cost of replacing 2.4GHz devices such as laptops and gaming devices and future dual mode GSM / Wi-Fi phones should 2.4 GHz interference force migration to 5 GHz.

We would question some key assumptions made in analysing the market demand and pricing for rural wireless broadband services. In particular :

- The model assumes users will pay premium for ‘benefits’ of symmetric (uplink down link speed) wireless broadband even when some of them have DSL as an option.
  - For example it seems questionable whether most rural businesses really will pay a significantly higher price per month for 4Mbit/s wireless service where a very much cheaper 512kb/s service via DSL is available.
  - The analysis would appear to suggests that the difference in user experience of 4 Mbps Symmetric service *vs.* 0.5-4 Mbps asymmetric service is enough to persuade the average business to spend £1800 p.a. for wireless broadband rather than £360 p.a. for DSL
  - Similarly we would question the assumption that residential users who can get 0.5-1 Mbps for £200 p.a. will be attracted to the 1 Mbps symmetric wireless service for £400 p.a as assumed in the study
  - We therefore suggest that the target market assumed in the study should be reduced by those businesses who are happy with <4 Mbps services and residential users who are happy with <1 Mbps.
- The model estimates that 40% of businesses will pay £150/month for wireless broadband based on a linear interpolation of the price/penetration of existing Satellite and DSL solutions. We believe the demand curve is not linear and the percentage of businesses prepared to pay this price has been very significantly over-estimated.

A detailed account of BT’s concerns with some of the key assumptions made in the Scientific Generics study can be found in Annex 3.

3. 2.4 GHz BAND

3.1 The Benefits and Drawbacks of Increased Power Limits

BT has undertaken some computer simulations to examine the impact of higher power Wi-Fi power levels on the coverage that can be achieved with Wi-Fi Access points and how the power levels affect the capacity/throughput of Wi-Fi systems in various different geographic scenarios (See Annex 2). This work has also looked at the impact of video senders that operate typically on 4 channels within the 2.4 GHz band used for Wi-Fi.

The simulations of the effect of the video senders on Wi-Fi networks have indicated that because these systems do not “politely” share the spectrum (they run continuously and do not co-ordinate at the Media Access Control protocol level) they have the potential to have serious adverse impact on Wi-Fi systems. The BT modelling work explored the impact of video senders operating at 20 dBm and at 30 dBm power levels. This modelling work found that for one of the WLAN deployment scenarios considered, with just a 5% adoption rate of video senders the RF coverage of Wireless LANs was further reduced by 12% and 25% more WLAN clients would not be able to connect to an access point.

The simulations of the effect of allowing higher power Wi-Fi levels have considered indoor and outdoor deployments in urban areas, as described in Annex 2. For 25% adoption rate in a dense environment, power increases above approximately 500 mW start negating coverage benefits due to interference and collision avoidance. Hence a modest general increase in EIRP (perhaps to a maximum of approximately 500mW) is supported by the studies.

3.2 Conducted *vs* Transmitted Power Limits

BT does not support a move to only specify maximum conducted power levels as that would lead to a situation where it is difficult to characterise the interference environment as maximum e.i.r.p. would be unknown. We prefer to have an e.i.r.p. limit specified.

3.3 BT’s proposed solution

On the basis of our experience of Wi-Fi deployments, the interference simulations undertaken by BT, as well as consideration of Wi-Fi power levels in some other countries (e.g. USA), we are of the opinion that it would be beneficial to consumers if Ofcom were to allow a modest increase in the present Wi-Fi power limit of 100mW e.i.r.p. We believe that allowing an increase to, at most, 500mW e.i.r.p. would yield significant benefits in terms of coverage, particularly within buildings, and the achievable throughput speeds of Wi-Fi networks, with only a small risk of increased interference to some users. We propose that this higher power should only be available to Wi-Fi devices which support full interoperability with 802.11 b and g devices (this includes normal operation of 802.11n devices).

We are however concerned that allowing higher power in only part of the 2.4GHz band will lead to a concentration of devices in that part of the band and leading to congestion problems that would not arise if the whole band had been available for the slightly increased power levels. To realise the benefits to consumers the small increase in Wi-Fi power levels suggested above would need to be available across the whole band. We urge Ofcom to negotiate further with MOD to explore the possibility of addressing the whole band.

4. 5 GHz BAND

BT supports the proposed increase in 5.8 GHz e.i.r.p. limits from 2W to 4W. We very much welcome Ofcom's proposal as this will improve the coverage and performance of broadband wireless access networks deployed in this frequency range. BT had requested Ofcom to make this change to the regulations and has been fully involved in the international technical studies that demonstrated that sharing with satellite systems is feasible in this band at this increased power level. We urge Ofcom to implement this change at the very earliest opportunity.

We have examined the draft revised Interface Regulation IR 2007 and believe that the reference made in several places to the relevant ETSI standard may be incorrect. We believe it should be **EN 302 502**.

BT agrees that the register of 5.8 GHz assignments should be open.

5. CONCLUSIONS

BT has carefully considered the issues relevant to the use of the 2.4 GHz and 5 GHz bands for licence-exempt devices and the consultation questions that Ofcom has posed. We do not support the introduction of significantly higher power 2.4 GHz wireless access systems in rural areas but would suggest a small general increase in Wi-Fi maximum e.i.r.p. levels to a maximum of 500mW would be beneficial to UK consumers. We support Ofcom's proposals for changes to the 5.8 GHz band regulations.

BT is willing to discuss any points in greater detail with Ofcom if required.

ANNEX 1: DETAILED RESPONSE TO THE CONSULTATION QUESTIONS

Q1: Have all the possible victims of interference been correctly identified and quantified as far as possible?

BT is concerned that Bluetooth devices have not been properly considered. We would point out that Bluetooth V1.2 is only frequency hopping if the data link is established.

Interference between high power wireless systems in rural areas and some conventional Wi-Fi use has not been considered.

Q2: Have the costs and benefits been correctly captured? In particular, are the costs of interference to WLANs appropriately assessed?

BT has a number of significant concerns with the costs and benefits analysis that are discussed in section 2.2 above and Annex 3, in particular some of the key assumptions made (and the conclusions that then follow). We note that the costs of interference from high power wireless systems is modelled as the cost of business 2.4GHz Wi-Fi users migrating to 5GHz and a £100 per user cost is assumed. We would question whether the impact for example on lap top computers or gaming devices with only 2.4G Wi-Fi built in, or future dual mode GSM/Wi-Fi mobile phones and the like are considered in terms of the costs of replacement and the domestic as well as business users have been considered.

Q3: Are there any other mechanisms that could be used to restrict device operation to appropriate areas? Of the schemes set out which should be preferred?

BT is of the opinion that all of the methods discussed in the document in terms of constraining high power wireless systems in part of the 2.4 GHz band to certain geographic areas are impractical and unworkable. We do not believe that a licensing scheme would be enforceable as we believe it would be impossible to prevent devices being located in 'prohibited' areas where significant interference to conventional Wi-Fi systems could occur.

Q4: Should we move from specifying radiated power to specifying conducted power?

BT does not support a move to only specify maximum conducted power levels as that would lead to a situation where it is difficult to characterise the interference environment as maximum e.i.r.p. would be unknown. We prefer to have an e.i.r.p. limit specified (a conducted power limit could perhaps be included in addition).

Q5: For 2.4GHz which of these options do you favour? Are there other viable options that should be considered? Or should regulations be left unchanged?

As explained in Section 3.3, on the basis of our experience of Wi-Fi deployments, the interference simulations undertaken by BT, as well as consideration of Wi-Fi power levels in some other countries (e.g. USA), we are of the opinion that it would be beneficial to consumers if Ofcom were to allow a modest increase in the present Wi-

Fi power limit of 100mW e.i.r.p. We believe that allowing an increase (perhaps up to a maximum of 500 mW e.i.r.p.) would yield significant benefits in terms of coverage, particularly within buildings, and the achievable throughput speeds of Wi-Fi networks, with only a small risk of increased interference to some users. We propose that this higher power should only be available to Wi-Fi devices which support full interoperability with 802.11 b and g devices (this includes normal operation of 802.11n devices).

We are however concerned that allowing higher power in only part of the 2.4GHz band will lead to a concentration of devices in that part of the band and leading to congestion problems that would not arise if the whole band had been available for the slightly increased power levels. To maximise the benefits to consumers the small increase in Wi-Fi power levels suggested above would need to be available across the whole band. We urge Ofcom to negotiate further with MOD to explore the possibility of addressing the whole band.

No other devices should be allowed to increase their power limits in the 2.4 GHz band as serious interference to large numbers of Wi-Fi users could result.

Q6: For 5GHz should Ofcom increase the power to 4W EIRP at 5.8GHz in accordance with ECC Recommendation and as set out in the draft IR2007? Should Ofcom open the database for public access to facilitate coordination?

BT supports the proposed increase in 5.8 GHz e.i.r.p. limits from 2W to 4W. We very much welcome Ofcom's proposal as this will improve the coverage and performance of broadband wireless access networks deployed in this frequency range. BT had requested Ofcom to make this change to the regulations and has been fully involved in the international technical studies that demonstrated that sharing with satellite systems is feasible in this band at this increased power level. We urge Ofcom to implement this change at the very earliest opportunity.

BT agrees that the register of 5.8 GHz assignments should be open.

ANNEX 2 : BT TECHNICAL ANALYSIS

Scope for higher EIRP limits in the license-exempt 2.4 GHz band

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Abstract—Wireless LANs [WLANs] are one of the fastest and cheapest ways of providing Broadband Wireless Access [BWA]. Increasing numbers of operators are rolling out "Wireless Cities" that provide a blanket Wireless Fidelity [Wi-Fi] coverage. This year BT has begun rolling out wireless infrastructure around 12 UK cities. Significant efforts are made to improve the spectrum efficiency and enhance the performance of broadband wireless services. Recently the UK telecoms regulator OFCOM has initiated an industry wide consultation to assess the potential impact of increased effective isotropic radiated power [EIRP] levels in license-exempt ISM band [1]. In this context our study assesses the benefits and risks involved in provisioning capacity and coverage at higher EIRPs. Using various modelling tools we try to understand some of the key issues at higher power levels, such as impact and evolution of interference and the behaviour of Collision Avoidance (CA) protocol. We study coexistence issues of i) public outdoor WLANs ii) private home WLANs and iii) other devices in the 2.4 GHz band at higher EIRPs. The study involves an in-depth technical analysis complimented with detailed analytical and experimental data. The study is performed in three different geographical regions with increasing densities at 100mW, 500mW, 1W and 10W EIRP levels. Based on the mathematical, simulation and experimental work, concrete recommendations are made about advantages and disadvantages of higher EIRPs systems.

I. INTRODUCTION

Although cellular operators provide country wide coverage, these systems have rather limited capacity, raise affordability issues for the customers and can require enormous investments for license spectrum and infrastructure. Cheap and ubiquitous broadband wireless access is what most of the operators are aiming for and WLANs offer a promising alternative/complement. To further improve the performance of public WLANs, extensive research is being conducted in various areas like MIMO, dynamic frequency selection, and adaptable power control. Another area of potential improvement is increasing the permissible EIRP in the 2.4 GHz band. The current EIRP limit for Europe/UK is 20 dBm or 100mW (public networks in France are one exception) and there is debate going on to raise it to higher levels. This has provided us with an opportunity to look at suitability of appropriate EIRP levels in varying household densities.

The scenario used for developing a simulation model comprised of a single outdoor Wi-Fi system providing a blanket outdoor coverage over an area of 1 sq km. This area also contains many independent home Wi-Fi networks. We consider power levels of all systems raised up from 100mW to 10W (using sample values of 100mW, 500mW, 1W and 10W). Client EIRP is maintained at 100mW (typical clients are nowadays less than this and power consumption considerations suggest that such an assumption may be appropriate). WLAN adoption rates of 1%, 5%, 10% and 25% of household density are considered for home Wi-Fi systems. All 12 overlapping channels are considered for home Wi-Fi systems while the managed public outdoor

Wi-Fi systems use a frequency reuse pattern of three non-overlapping channels (Channel 1, 6, 11). The number of outdoor Wi-Fi systems was 40 in the given area. The number of clients per AP was arbitrarily chosen to be 5. Interference considered is co-channel interference (CCI) and adjacent channel interference (ACI), along with external interference such as video senders in the 2.4 GHz band. ACI is the interference caused by adjacent channels that have spectral overlap in frequency domain of the client channel. CCI is the interference caused by nearby WLANs that are using same channel or frequency of the client channel. We do not study the 5GHz band.

The study is divided into the following sections. Section II provides the test results based on field measurements and lab experiments. Section III describes the technical analysis done for studying the different power levels using MapInfo/MapBasic and ns2 simulations, Section IV provides discussion about the study results and finally Section V provides the conclusion of the study.

II. FIELD MEASUREMENTS

Tests were conducted to understand and measure the impact of interference. Figure 1 shows the WLAN deployment in a local area using Ekahau, GPS receiver and Netstumbler software [2]. The nearby WLANs introduce the ACI and CCI problem and are shown in the green shades of the map. The 2.4GHz unlicensed band is crowded with growing number of other devices. Similarly, other site surveys were done in five different geographies to understand the impact and evolution of interference.

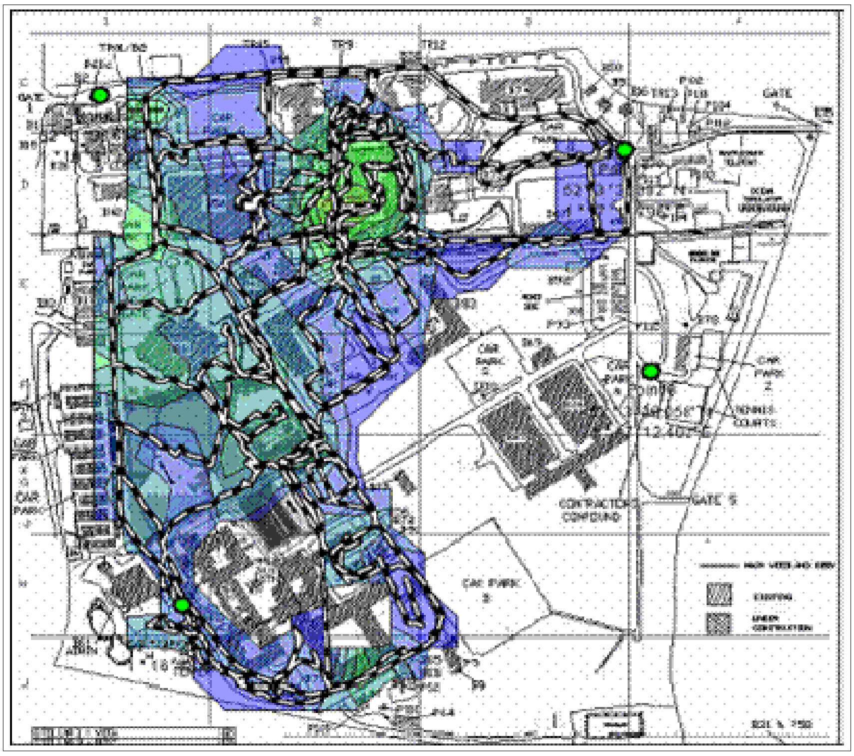

Fig. 1. Radio coverage of campus WLAN deployment

To operate at higher EIRP, a special Test and Development (T&D) radio licence to operate up to 10W (40dBm) was obtained from OFCOM. Outdoor radio measurements were performed in a test range facility to validate and calibrate the RF model. This included tests to determine the range, bit error rate (BER) and throughput relationship at higher EIRPs. Experiments to understand the impact of high EIRPs **in high densities** are difficult to carry out in an outdoor environment. Ignoring propagation subtleties, it is possible perform the experimental work at lower powers in a lab set-up and scale the results to representative higher power levels. Few access points and clients were set at scaled down transmit powers and spaced a few metres apart to simulate the physical separation between devices. Different channel schemes were chosen to study intra-cell interference. Effects of other interferers such as video senders and blue-tooth were measured as well. Distributed Internet Traffic Generator (DITG) [3] was used to generate different test traffic mixes.

III. TECHNICAL ANALYSIS

For the purpose of the study a household density within one sq km area is used as an abstraction for representing the wireless device density. A residential environment constitutes different house types such as bungalows, semi-detached, detached, flats, etc. The dense environment is represented by ”Soho” and comprises of 5000 houses/buildings; the urban environment is represented by ”Ipswich Town centre” and comprises of 2500 houses/buildings; and rural is represented by ”Westerfield” village and comprises of 200 houses. The region database has information about household density, house layouts, streets, railway lines and rivers in MapInfo database [4] format.

An appropriate adoption rate of devices is modelled into each region. The channel assignment scheme and AP location for outdoor access points [APs] is a managed scheme using 3 non-overlapping channels, while for home Wi-Fi the channel scheme is based on the distribution pattern extracted from site-survey results using all 12 overlapping channels. Clients are randomly distributed within 15m of radius from the home Wi-Fi, representing private home clients. Some of these clients fall inside the house while some fall outside. Using simulation we attempt to create three maps for each region (i) pathloss map (ii) interference (iii) collision avoidance map as discussed below.

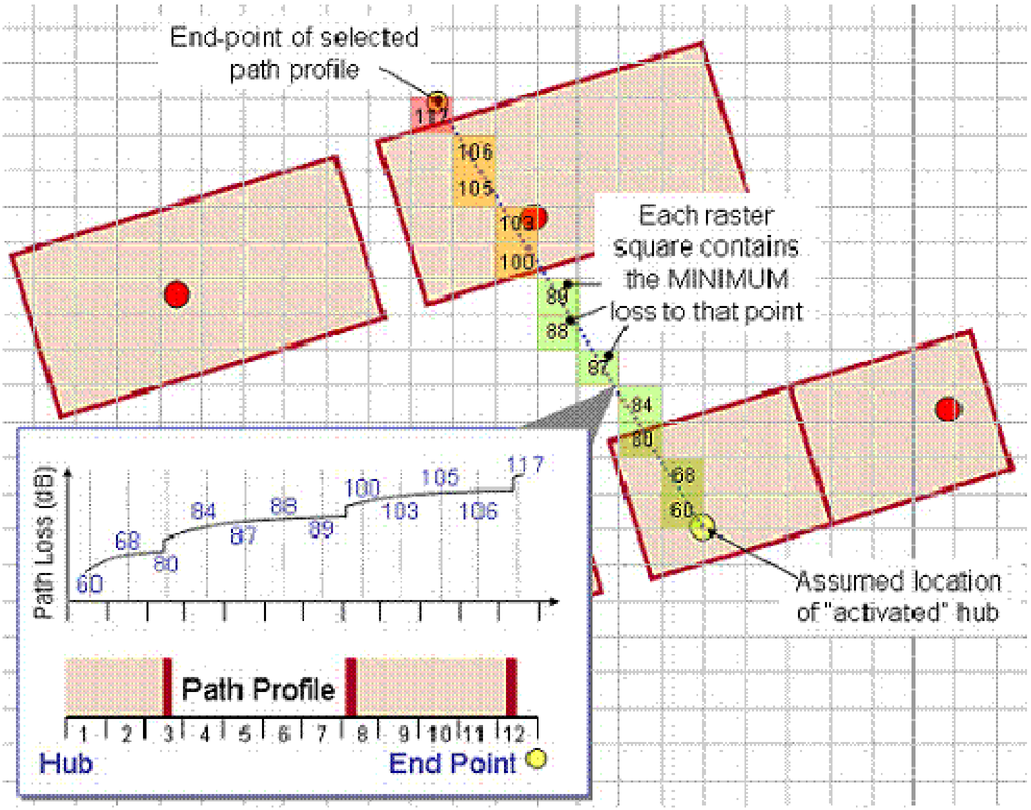

Fig. 2. Pathloss map

Each region is divided into a raster cell grid of small 2m x 2m squares. For each activated AP, RF coverage is plotted as shown in Figure 2. A random number (0 to 1) is assigned for each house/building in the area. WLAN adoption rate is chosen for the area and all houses with random number less than the adoption level are activated. Based on link budget calculation appropriate maximum range of RF coverage is assumed and path profile is built from the hub to each raster cell within its RF boundary. Appropriate radio propagation models based on the UMTS Mixed indoor outdoor model [5] and Multi-Wall-Floor (MWF) model [6] are used for link budget analysis. Pathloss values for each raster cell is calculated based on factors such as distance, number of internal/external walls traversed, power levels, etc. If two or more APs build a path profile to the same raster cell, the AP with minimum pathloss value is selected. These results produce a "minimum path loss map" for every selected AP. Pathloss maps are generated for outdoor WLANs but with a slightly different propagation model. Similarly interference map stores the interference level for each raster cell. Signals coming from nearby WLAN's are accounted in the interference map after considering its signal strength, channel overlap factor based spectral envelopes [7], coding techniques and receiver side parameters. If the signal strength from nearby co-channel APs is measured to be above a certain Radio Signal Strength Indicator (RSSI) threshold, they are updated in the collision avoidance map instead. In this state, if the interfering signal is on the same channel and is higher than a certain RSSI threshold it results in a contention of the channel due to CSMA/CA protocol rather than being treated as co-channel interference.

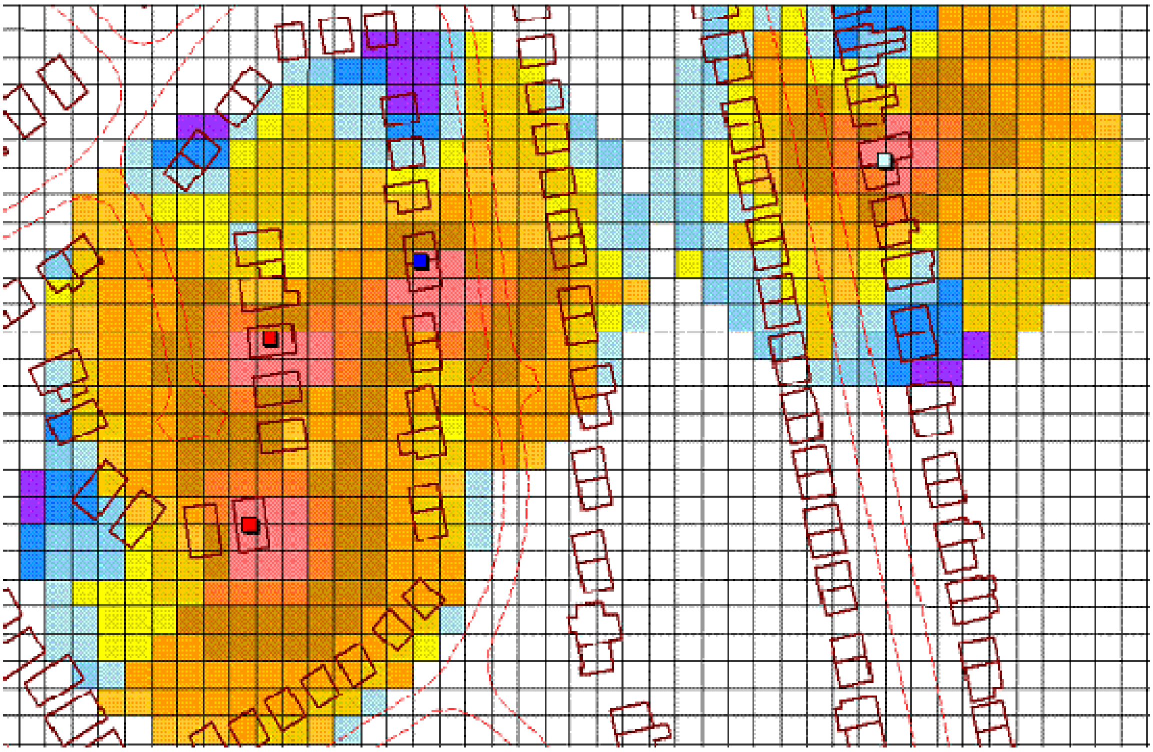

Fig. 3. Pathloss map

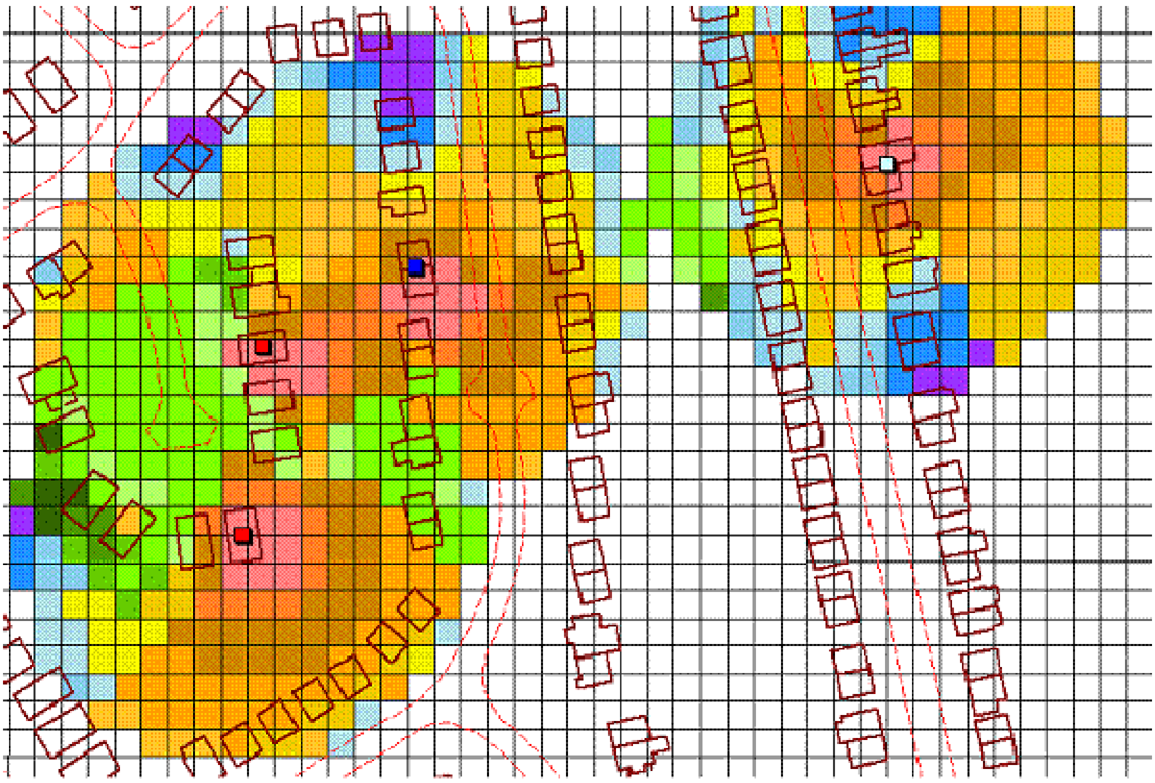

Fig. 4. Interference map (affected grid cells shown in green colour)

The findings of the test measurements along with the simulation work are extrapolated across the entire region using a tool written in MapBasic/MapInfo software. MapInfo is desktop software to perform mapping and geographical analysis. MapBasic software is a programming and application development environment on top of MapInfo. Figure 3 shows a pathloss map for the area. The brown rectangular objects indicate the outline of houses and red dashed lines indicate road edges in the area. The activated houses are marked with blue, green, red squares representing channel numbers. The yellow-orange coloured grid cells signify low pathloss areas while blue/purple coloured grid cells signify higher pathloss regions. A high number of walls or greater distance between the grid cell and AP lead to high pathloss areas where connection may not be possible. WLANs and other devices in the neighbourhood may contribute as interference if they overlap with client channel. Interference is modelled and shown as green regions in the interference map as Figure 4. For a higher WLAN adoption rate the reduction in coverage and capacity due to interference is considerably high. Similarly other interferers like Bluetooth, and video senders are modelled as well. This exercise is carried out for different adoption rates with different household densities at various power levels and the final statistics are gathered. The three maps (pathloss, interference and collision avoidance) form a basis for a wide variety of analysis including coverage, capacity and interference studies. For example the pathloss map can be easily converted into a coverage map based on a minimal SNR threshold needed for connectivity or can be used to determine the service and terminal requirements. Thus the combined study of experimental measurements, demographic data and simulation is considerably accurate and provides better insight about the expected capacity, coverage and interference results.

IV. STUDY RESULTS

Ideally, higher EIRPs should lead to improved coverage and capacity due to higher SNR resulting in better modulation techniques with lower bit error rates. But there are certain factors such as interference and collision avoidance constrain the system performance at higher EIRPs. Extensive simulations were run under set of following assumptions.

(i) The maximum range of connection of 'outdoor clients' was relaxed to permit operation as far as the link budget allows. This assumes either the receiver sensitivity at the AP is sufficiently low to connect conventional Wi-Fi clients at 100mW or that the clients operating at higher EIRP power as well. The later case can be attributed as a fixed wireless access scenario. Range of connection for 'indoor clients' was 15m radius around the home AP.

(ii) The range and location of all clients was the same for all EIRP levels (i.e. 75m for outdoor system and 15m for indoor systems at baseline EIRP of 100mW. The power level of all systems is raised to a test value, with clients operating at conventional 100mW).

(iii) The outdoor public network was not redesigned for the different EIRP levels.

A. Effect of Interference

Based on assumption (i), Table I summarises the average SINR per outdoor client for various WLAN adoption rates (1%, 5%, 10% and 25%) at increasing EIRP levels. The table shows two trends. Firstly, with any EIRP level the SINR degrades progressively in higher density due to the rising interference level. The minimum SINR threshold needed for connectivity is 10 dB. Secondly, the transition point for optimal EIRP manifests around the 10% adoption rate beyond which there is no improvement in SINR (from 500mW to 1W). For 25% WLAN adoption rate, 500mW

EIRP level provided the best SINR as compared to other EIRPs. Different densities provide different optimal EIRP level.

TABLE I

AVERAGE SIGNAL TO INTERFERENCE & NOISE RATIO

Adoption rate/ EIRP	1%	5%	10%	25%
100mW	16 dB	15.1 dB	14 dB	11.3 dB
500mW	18.6 dB	16.7 dB	16.5 dB	12.8 dB
1W	19.4 dB	17.5 dB	16.7 dB	12.4 dB

One illustration of rising interference is shown in Figure 5. Any increase in EIRP results in the level of interference observed by clients increasing.

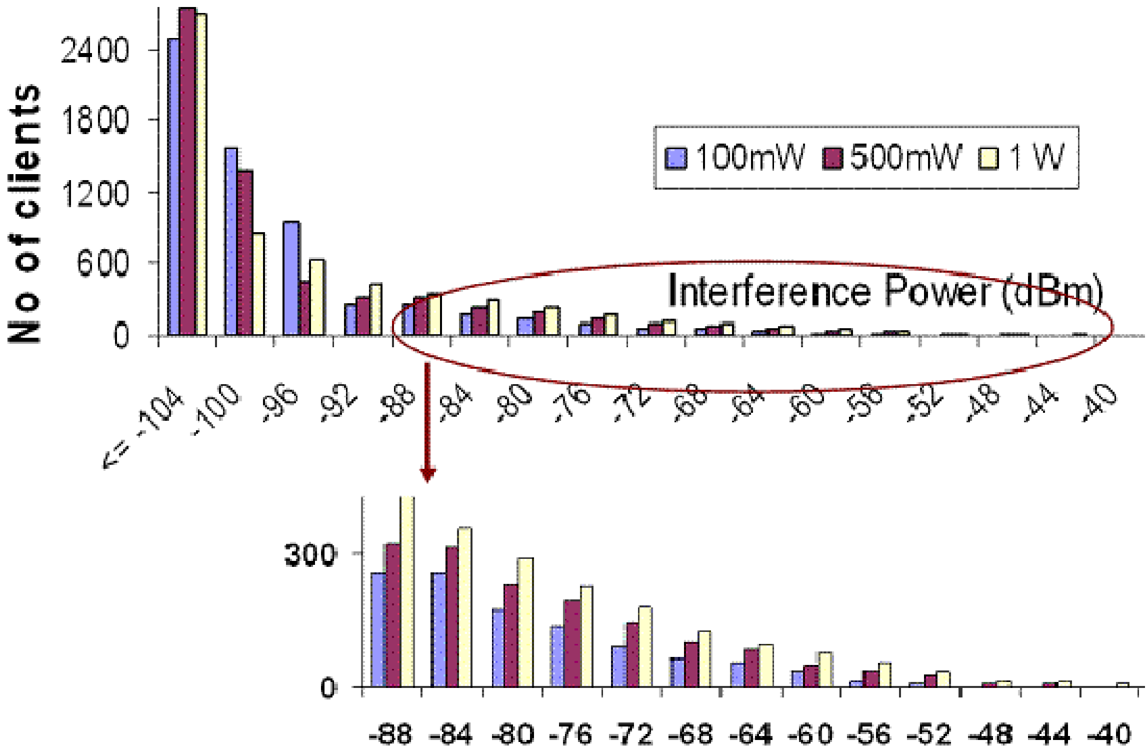

Fig. 5. Interference histogram at 100mW, 500mW and 1W in a 'dense' environment

Table II further summarizes the number of clients disconnected due to rising interference. For 5% and higher WLAN adoption rates, increasing percentage of clients is disconnected from previously connected locations. 500mW provided the least number of clients disconnected for 25% adoption rate as compared to other EIRPs. At 100mW, signal strength at the clients is not sufficient to tolerate interference in dense environments as seen by lower SINR resulting in high percentage of clients being disconnected.

TABLE II

PERCENTAGE OF CLIENTS DISCONNECTED

Adoption rate/ EIRP	1%	5%	10%	25%
100mW	2.5%	8.4%	14.7%	37.5%
500mW	1.7%	7.6%	12.5%	26.7%
1W	0.9%	12.5%	14.2%	33.3%

B. Effect of Collision Avoidance protocol

At higher EIRPs clients are affected not only from high interference but also from collision avoidance. There is a benefit of extended coverage at higher EIRP, but to gain this benefit, the receiver sensitivity of outdoor APs needs to be low enough to listen to distant clients (clients operating at 100mW). With lower receiver sensitivity or higher EIRP clients, the system would be symmetric in uplink-downlink link budgets. But with a symmetric system, the AP can listen to many more clients and devices at extended distances as well. These clients if operating on same channel would cause the AP to back-off more often. Figure 6 shows how the number of undesired co-channel clients captured per outdoor AP increases significantly at higher EIRPs. The number of co-channel clients shoots up with increasing EIRP and increasing density. Performance of such outdoor systems is thus constrained by CSMA/CA protocol leading to significant capacity degradation. In dense environments, this worsens especially as the contention and back-off is at the AP end. In an asymmetric system, the only benefit for clients is use of adaptive modulation schemes to gain better downlink throughputs. Range test results of test kit at 40dBm showed downlink range was about 900m while uplink range was just 550m.

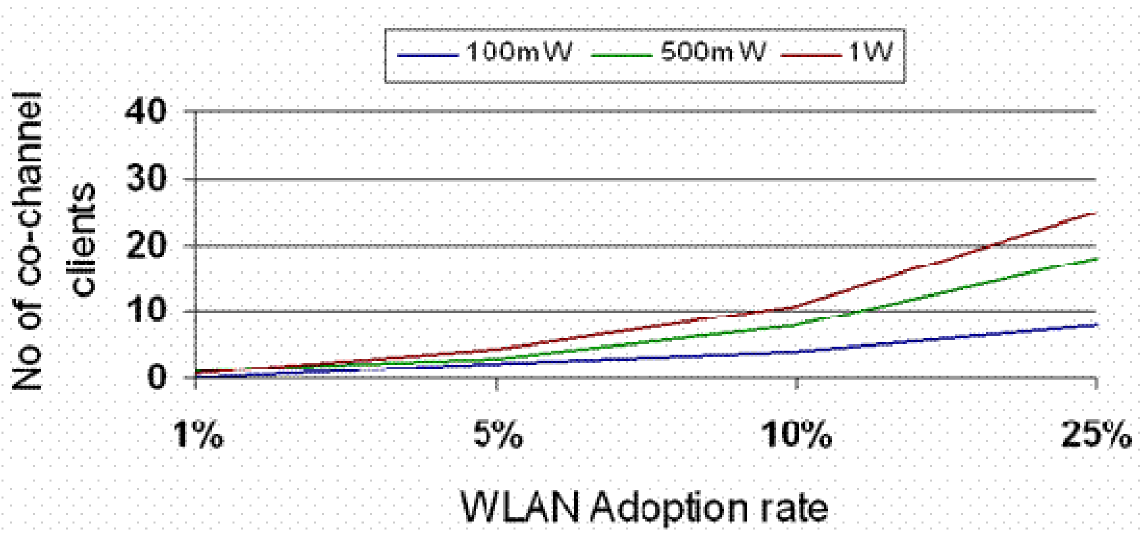

Fig. 6. Number of undesired co-channel clients captured per 'Public WLAN AP' at different power levels

C. Effect on coverage and capacity

Based on assumption (ii) Table III summarizes statistics related to coverage gain or improvement; interference rise; and system capacity (defined as number of APs X average throughput per AP) when moving from 100mW to 1W. As we move to dense environments, **improvement** in coverage and system capacity reduces. The percentage of clients failing to connect goes up. There is a reduction in operating margin of 6dB, 8dB and 9dB on an average basis due rising interference level and 9dB scenario.

TABLE III

CLIENT STATISTICS FOR RISE FROM 100MW TO 1W

EIRP/ Region	Coverage gain	System capacity	Client failure	Avg Interference rise
Rural	3 times %	20%	0%	6 dBm
Urban	1.3 times %	12%	8%	8 dBm
Dense	1.1 times%	8%	11%	9 dBm

This reduction in operating margin is shown in Figure 7. The power level when increased from 20dBm (blue) to 30dBm (red) results in proportionate rise of interference level from yellow to green (by about 9dB). Higher EIRP for other applications like video senders, microwave, and blue-tooth is extremely detrimental. Video senders, considered as external interference, have operational range of up to 15m in residential environment and use wideband FM modulation. With just 5% adoption rate of video senders, RF coverage is further reduced by 12% and 25% more clients are disconnected.

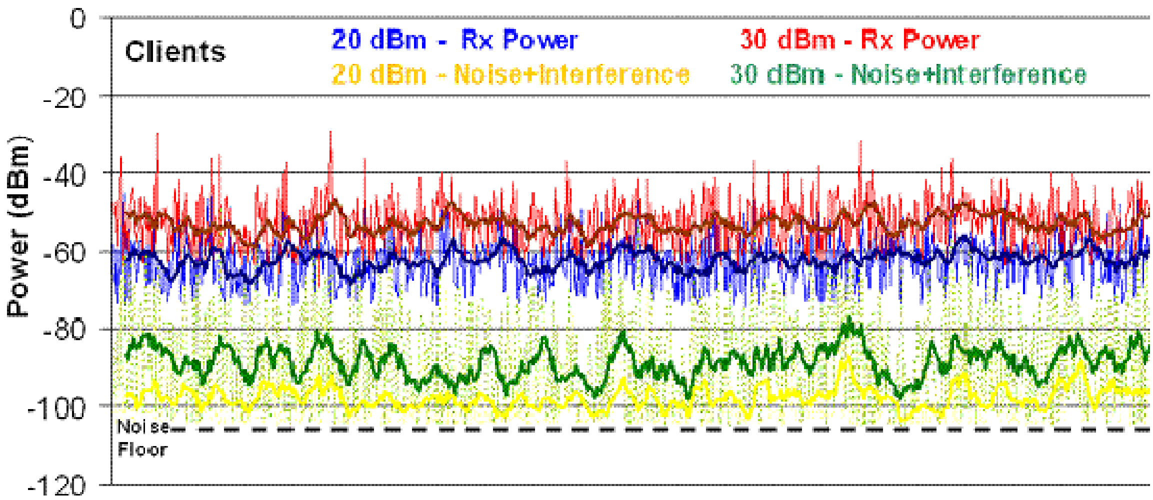

Fig. 7. Rise of signal and interference level in 'dense' environments

Interference (along with collision avoidance limitation) results in no net improvement in average client throughput. Figure 8 shows the throughput histogram for an urban environment. At higher EIRP, greater percentage of clients fail to connect (shown as negative numbers) from locations previously able to connect. Few clients get very high throughputs, but for most of the remaining clients there is no benefit of higher EIRPs.

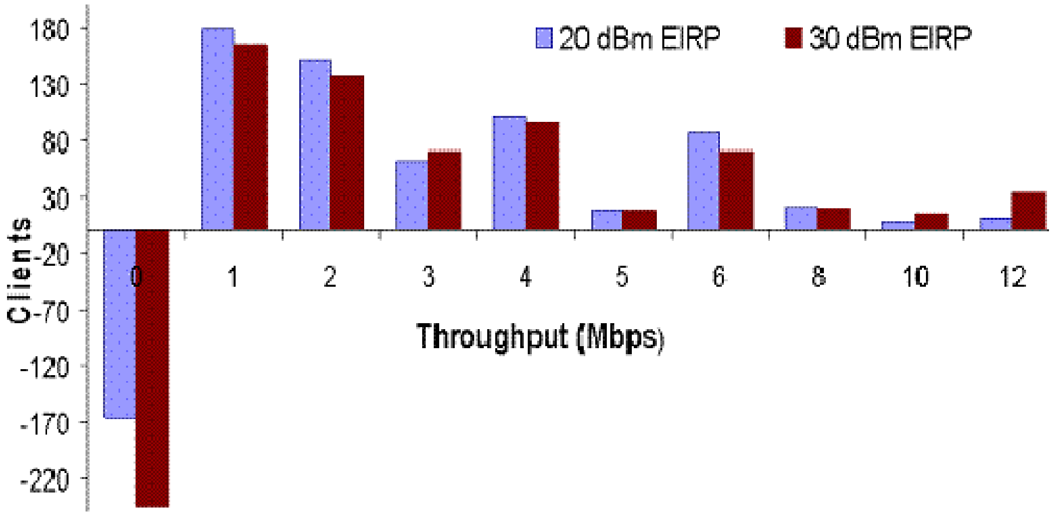

Fig. 8. Throughput histogram at 20dBm and 30dBm in an 'urban' environment

Note:
The throughout histogram is function of client SINR. The negative numbers on the histogram show the number of clients receiving 0 Mbps or having SINR less than a required minimum threshold. Increasing number of clients get disconnected due to interference rise at higher EIRPs.

V. CONCLUSION

Our study provides answers to some of the key technical questions related to performance of broadband wireless systems at higher EIRPs.

- It shows optimal EIRP is a function of density and with increasing density, interference and collision avoidance protocol restricts the performance.
- Interference rises proportionately in dense environments, with external interferers being the most detrimental. We strictly rule out the option of increasing EIRP to other non 802.11 compatible devices in the 2.4 GHz band.
- There is also some risk of asymmetric uplink-downlink systems that would take away the benefit of significantly higher EIRP.
- Assuming symmetric link budget at higher EIRP, the functioning of 802.11 collision avoidance restricts any further capacity improvement.
- Modest to high coverage improvement is achievable based on density of the area.

From the simulation results we conclude that higher EIRP performs well for rural, town and semi-urban areas in terms of improved coverage and capacity. For 25% adoption rate in dense environment 500mW seems to be the uppermost EIRP limit. Any power increase above this limit starts negating the benefits due to interference and collision avoidance. Hence a modest increase in EIRP to a maximum of 500mW is recommended.

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ANNEX 3 : BT DETAILED COMMENTS ON ECONOMIC STUDY

Introduction

The Scientific Generics analysis on the potential market for fixed wireless services contains an attempt to quantify the benefits of extending broadband services using fixed wireless access and the costs of mitigating the impact of these increased power levels on legacy services and equipment. BT is concerned that these values appear to significantly over estimate the current opportunity for an increase in power levels.

The arrival of a number of inclusive broadband packages on the market and ongoing price erosion on stand-alone services has meant that the market has become far more price conscious.

Basic Assumptions

BT does not agree with all the assumptions made in the document by Scientific Generics. This section highlights BT's concerns with these baseline assumptions. The text in boxes is quoted from the Scientific Generics report.

1. Within the 6 year timescale of our model, target WBA users are those who either cannot get DSL at all, or who can only obtain DSL of a degraded quality. Thus for residential users a speed of 1 Mbit/s will be acceptable.
2. The main broadband application for residential users in rural areas over the next 6 years will remain web browsing and downloading of small to medium sized files, and is unlikely to include services such as high quality video streaming that require download speeds in excess of 1 Mbit/s.

The report does not provide any explanation as to why users will need services of more than 1 Mbit/s. It acknowledges that this bandwidth is not enough to support high quality video streaming and so BT questions what applications are driving this arbitrary level of 1 Mbit/s.

3. Business users will require speeds higher than residential customers, because they typically need to transfer larger files, handle multiple users and are more sensitive to delays in sending and receiving information. A 4 Mbit/s connection will be adequate for most typical business users.
4. In rural areas where DSL is available, speeds are likely to remain limited due to the limitations of the local loop. Although BT may enable most or all of its exchanges in the near future many residences and businesses are too far from their local exchange to be able to obtain a DSL connection of sufficient quality.

Again, this split appears to be arbitrary. Although many businesses would be able to benefit from a higher speed service, many may not require the increased bandwidth. Since most businesses using e-commerce techniques to serve their customers will use a hosted server facility, many companies will only require broadband connectivity for email and simple web browsing. BT acknowledges that there will be businesses that can benefit from the higher speed services, but that many will be governed by price and will take a lower speed, lower priced DSL service if available.

5. Actual WBA services are likely to be symmetric, and (where there is footprint overlap) will mostly compete with asymmetric DSL services. WBA operators will need to sell the benefits of symmetric services to compensate for the likely higher price of WBA (even in areas where DSL is unavailable or low quality).
6. Demand of broadband services is not dependent on network architecture, rather demand is common across all potential consumers, therefore residential and business users will require contention ratios and download limits comparable to equivalent DSL services currently provided.

These two points appear contradictory. In point 5, Scientific Generics is justifying charging more for service on the basis of network functionality, but saying in point 6 that demand is common across all customers.

Whilst BT would accept that customers would gladly accept a higher rate service (in either uplink or downlink) many of them are unlikely to be willing to pay a significant premium for such services.

Pricing

The pricing suggested in the Scientific Generics report is:

- £35 per month for residential
- £150 per month for business

When both residential and commercial DSL services can be obtained for less than £25 per month, these figures seem high. They appear to be based on the required price to be charged to cover the increased costs of delivering broadband service wirelessly, rather than a reflection of true market based pricing. The model assumes that users will pay a premium for the perceived 'benefits' of wireless broadband even when some of them have DSL as an option

The pricing assumptions in the Scientific Generics report make use of the elasticity curves shown in Figure 1 below. The concern that BT has is whilst these curves are probably a good representation of the elasticity of the market in isolation, they are not representative of a market where ***a cheaper option exists***.

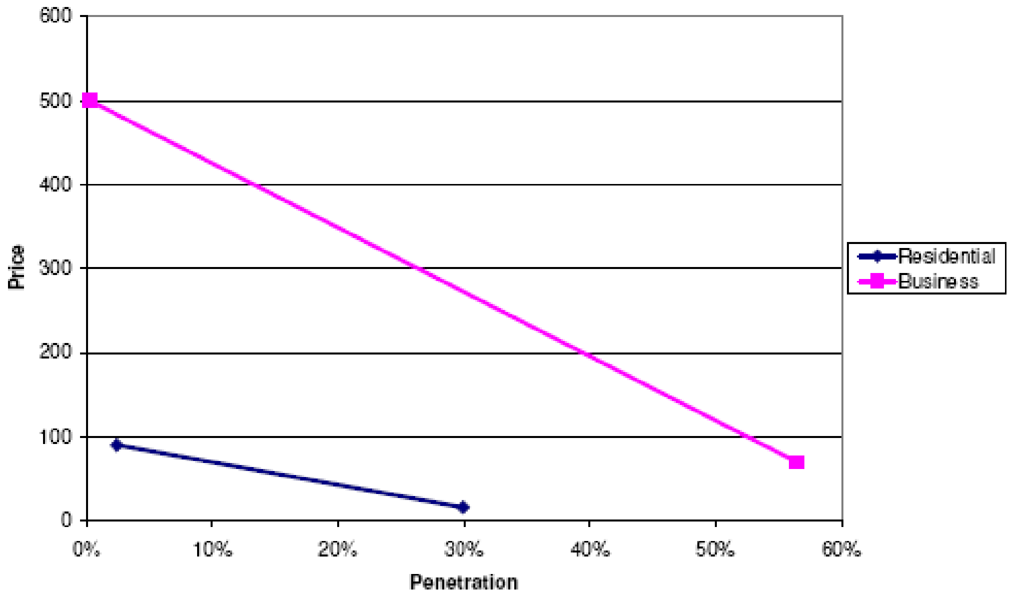

Figure 1 - Price Elasticity Curves from Scientific Generics

The studies are said to assume that equipment used is conformant to 802.11g at 2.4 GHz and 802.16d (i.e. 802.16-2004) at 5.8 GHz. It is not clear that such systems will have the capacity to provide 4 Mbit/s at edge of cell without adversely affecting the overall cell capacity – due to the use of adaptive modulation and coding. However, if we assume that the delivery of a 4 Mbit/s service is feasible across the area of the cell, the analysis also suggests that the difference between 4 Mbit/s and 0.5-4 Mbit/s and symmetric vs. asymmetric service is enough to persuade the average business to spend £1800 p.a. for wireless broadband rather less than £300 p.a. for DSL.

As already suggested, the pricing elasticity curves do not indicate what percentage of users would be willing to pay a premium for enhanced speeds. For many businesses, especially non technology companies, always on email access is a key feature rather than speed. This can be delivered on either network. Therefore, BT proposes that the analysis should consider that only a proportion of those users that would be willing to pay a certain price for broadband service would be willing to do so in the presence of a ***cheaper alternative*** as many would be unable to monetise the benefits of higher speed and service symmetry.

Again, many residential users who can get a service of up to 1 Mbit/s for just over £200 p.a. will not be tempted by 1 Mbit/s symmetric for £420 p.a.

BT proposes that the target market should be reduced by those businesses who are happy with <4 Mbit/s services and residential users who are happy with <1 Mbit/s.

Discussion

The market segmentation should be divided into two main groups:

- Those users who cannot get any broadband
- Those users who want higher speed than DSL can offer

It is anticipated that a far lower percentage of users would be happy to pay a premium for wireless broadband if they can be served by DSL. People willing to pay more will need (or believe they need) higher bandwidths. Many will be happy with 10 times dial up speeds and an always on connection (which is fine for basic browsing and email). BT suggests that a reasonable assumption for those users that would be willing to pay the premium for higher bit rates is around 20% of the predicted market.

The Scientific Generics study suggests that, on the basis of the price elasticity curves, the service would connect 19% of unserved households and 39% of unserved businesses. This equates to a total customer base of 170,871 for the highest power scenario, generating revenue of £218.8 million.

If we accept that a more accurate definition of unserved businesses is those who are unable to get any DSL service and 20% of those who are able to get a service of up to 4 Mbit/s and that the definition of unserved consumers is all of those who are unable to get any DSL service and 20% of those who are able to get a service of up to 1 Mbit/s, then the total customer base falls to approximately 57.5k consumers and 26.5k businesses[1]. This would generate revenue of £71.9 million.

BT does not have the information to provide a revised calculation of the number of economically viable cells in the same manner as the Scientific Generics study. However, it is clear that with a reduction in revenue by two-thirds, the number of viable cells will be far lower.

Estimate of Costs

Scientific Generics also states "An estimate of £100 as the cost per user for replacing a 2.4GHz LAN adapter and share of an AP with a 5.2GHz one". Whilst this is probably a realistic estimate of the costs associated with upgrading the infrastructure of a business to cope with interference, it makes no attempt to quantify the costs of upgrading or replacing terminals.

Most laptops currently ship with an 802.11b/g WLAN capability. Adding 5 GHz 802.11a will mean that users would need to add an additional PCMCIA card (typical high-street price £40[2]). Whilst this approach can be taken with laptops, Wi-Fi capability is appearing in many other devices now, such as wireless media players, games consoles, phones, PDAs and networked cameras. For many of these devices,

[1] BT Wholesale's prediction tool suggests that 96% of lines can support a ≥ 1 Mbps service and 78% of lines can support a ≥ 4 Mbps service when using DSLMax

[2] e.g. Netgear WAG511 Dual Band - http://www.dabs.com/ProductView.aspx?Quicklinx=2N53

a simple upgrade will not be possible and a complete new unit will need to be purchased.

BT is also very concerned about the potential impact of higher power video senders being permitted. The consultation is not clear about whether it is proposed to limit higher powers to devices that conform to IEEE 802 standards or not. With the proliferation of digital television, analogue video senders are become far more popular to share the output of a set top box around a house. These devices are typically mains powered and non-portable. They could therefore readily support higher powers. The main problem with these devices is that they transmit continuously, often even if television is not being watched, and so could sterilise large amounts of available spectrum if operating at higher powers that typical wireless LAN devices. The costs associated with mitigating the impact of higher powered video senders does not appear to be considered in the report.

Conclusions

BT is concerned that the report by Scientific Generics overestimates the potential market for wireless broadband services and underestimates the costs associated with migrating users to higher frequency bands. This means that the overall net benefit calculation is significantly overestimating the impact of higher powers on providing wireless broadband access.

BT is also concerned that devices that do not co-operate with WLAN standards may also be permitted to use higher powers in the band. Although the study by Scientific Generics considers the impact of higher powered WLAN services on devices such as video senders, it does not address the potential cost impacts of interference in the other direction.

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